The Clean Green—Phytoremediation

The program opens with scenic images of plants, trees, and grasses slowly dissolving together over a slow, powerful musical soundtrack.

> **Narrator:** Plants are vital.........Essential to all life on earth..........They process our air, water, and soil......They provide food and medicine......Plants have adapted to survive in some of the earth's harshest environments, evolving into over 380,000 different species.

A shot of a hand reaching for a plant is seen. The viewer then sees Dr. Scott Cunningham, a leader in phytoremediation research, and a colleague working in a greenhouse.

> **Narrator:** This unique ability to adapt and survive is now being put to work by environmental remediation researchers. The science of Phytoremediation, of using plants to control contamination, holds great promise as an effective and inexpensive means of cleaning up hazardous waste sites. Although still developmental, "The Clean Green" holds great potential.

The title of the program "The Clean Green" becomes superimposed over an image of a plant. The title fades out and an interview segment with Dr. Cunningham is screened. Shots of Dr. Cunningham working in his lab then cover his statement.

> **Scott:7:00:53:00** Phytoremediation is a fairly new concept. Perhaps 5 or 6 years old. But it builds on the traditions of plants and their ability to influence their environment around them.
> **Scott:7:02:05:00** People began to look at the use of plants for a number of very specific reasons. One is that many of our traditional remediation techniques are either too expensive or didn't work really. Pump and treat systems is one case in point where you could pump and treat a particular area for 100, 200 years and still not remove the contaminant trapped in the soil itself. **7:02:34:00** Plants, on the other

hand, can do this much more efficiently. They are solar driven, they pull water from the roots much like engineering pumps do and they treat that water through actually a biological system. They can either change some of the organics in the water stream or bind the metals, or sometimes even pull the metals up under the top.

Shots of a reed bed at a waste water facility are seen

Narrator: For years, the waste water industry has known the benefits of phytoremediation by using constructed wetlands, reed beds, and floating plant systems as a final conditioning phase. The environmental cleanup industry is now seeing how the unique properties of plants can be used as a remediation solution.

A 2-D graphic of a simple plant is then seen as the narrator explains how transpiration works. Parts of the graphic are highlighted as the process is defined.

Narrator: Think of a plant as a solar driven pump. What happens is sunlight hits a leaf and evaporates, or transpires water. This evaporated water demands more water and begins pulling moisture from the roots. The root system in turn explores the soil structure surrounding the roots, pulling or pumping large volumes of water up to the leaves.
When high concentrations of toxic contaminates are introduced during this searching process, most "normal" plants die.

The 2-D plant graphic appears again as the narrator details how phytoremediation works. The viewer sees the transpiration process again, but this time the plant also transpires toxic substances. The graphic and the copy illustrate the different ways contaminates can be processed.

Narrator: There are certain plants though, known as "hyperacumulators" that have the ability to hold or concentrate toxic contaminates at levels that are 100 times greater than what's considered normal.

Two distinct techniques are being used to put these special plants to work:

During phytostabilization migrating toxins are stabilized by using soil conditions and vegetative cover to contain the pollution.

During phytodecontamination the pollutants are actually converted into non-toxic materials or are accumulated in the plant and then harvested.

The graphic then dissolves into close up shots of plants at Dr. Cunningham's greenhouse.

Narrator: These "hyperaccumulator" plants are now being studied and cross pollinated with other plants to develop hardy, efficient strains that can thrive in foreign surroundings.

Dr. Cunningham's voice is heard again as he explains a particular plant

Scott:7:18:35:00 All the plants on this table are a part of the brasica family. The same family that cabbage and cauliflower and broccoli are in. They are remarkable plants. One plant, found in Belgium, this plant here is a zinc junkie. It needs zinc. It sucks up so much zinc from it's soil that 3 to 5% of it's total dry weight is zinc. **7:18:56:00** Unfortunately, this plant is two years old, it is incredibly small. We want to take what is good about this plant and move it into other plants. For that, we have chosen a molecular workhorse called a rabbidoxis This plant goes from seed to seed in 6 weeks. **7:19:14:00** We have a number of different ecotypes collected from all around the world. We are looking at the ability to take up the lead, hold the lead in the root, translocate and tolerate it. It is a remarkable plant.

A montage of plants dissolving together, similar to the opening appears. Then shots of the planting crew at the J-Field site are seen.

Narrator: It's clear that research is key to phytoremediations success. Industry, academia, and government agencies are all working together in the hope of finding an alternative to conventional methods that's cost effective, non-disruptive, and safe. The US EPA is currently conducting a 3 year, field scale pilot study at the U.S. Army's Aberdeen Proving Ground in Maryland using poplar trees to remediate volatile organic contaminates in an area that's a habitat for endangered and threatened species.

Shots of wildlife at the site are seen as George Prince, an environmental scientist for the for ERT explains:

George Prince: 3:11:17:00 Well, it is a very sensitive ecosystem. There's bald eagles that live in the area, we have nesting Blue Heron in the area, there's Osprey and a number of other species. A significant quantity of deer live in the area. So it's an area that we would like to protect from chemical contamination.

3-D animation helps illustrate the remediation process at the site.

Narrator: The test site is located on a remote peninsula, known as J-Field, where discarded munitions and solventswere placed into disposal pits, ignited, and burned. Over time, the underlying ground water has become polluted with volitile organic contaminates and is leaching into the adjacent marshland.

The study calls for poplar tress to be planted in a "U" shaped formation around the disposal pits, effectively creating a barrier that will draw upon the water table and slow or stop the discharge into the marsh.

The site was chosen for the study after traditional remediation methods were considered impractical.

Rich Tobia, the task leader for the site describes why traditional remediation methods weren't used.

Rich:3:26:02:00 We've actually been working down in this area for over two years now, we did some soil gas work in this area, We thought about putting in a soil vapor extraction system. That fell through due to the high ground water in this area and also the contamination is not in the upper part of the soil. It is down deeper in the actual aquifer. **3:26:26:00** We've also looked into pump and treat at the site. Pump and treat is very difficult at the site due to the very low flow rates you can get out through the wells down here.

Harry Compton, the environmental engineer at the site then explains why poplar tress were chosen. He also compares phytoremediation to traditional technologies. Shots of the planting process cover the sound bite.

Harry: 2:01:36:00 What we are doing here is planting some poplar trees that are very fast-growing trees and are tollerant in the kinds of contaminants that we see in the ground water here. The idea is that these trees are going to grow relatively quickly, create a rather dense root zone or root mass to suck up the ground water and with it the ground water contaminants and either entrain it in the root mass itself or translocate it through the tree and possibly metabolize it and volatilize it out through the leaves, but this is still all experimental and it is a field pilot scale project at this point.

The narrator explains a few particulars about the site as images of the specialized planting process are seen.

Narrator: For the test to be successful, the trees need to feed primarily from the contaminated aquifer, not from rain water. To assure this, special measures were taken.

-Holes were excavated through a layer of course sand so water would continue to flow to the capillary fringe of the root zone.

-Various engineering methods were used to limit rooting in the upper soil, where the air exchange and nutrients are more plentiful.

-And to guarantee the developing root system receives enough oxygen, air shafts were installed.

-Rainwater diversion trenches were also dug.

Ed Gatliff of Applied Natural Sciences, the phytoremediation contractor at the site, then describes the air shafts. Shots of the team installing the shafts are seen.

Ed: 2:28:57:00 Well some of this is a precautionary, as much as anything, these trees will pump their own oxygen down to the root system as they mature. I've seen trees like this stand, and live in standing water all summer long and be fine. But at the same time when we're just getting the tree started and we want the root system to develop to the level, to the depth that we're striving for, we want to take every precaution, and one of those precautions is to have a vent to help the air...gas exchange, help oxygenate the soil down there for the maturing root system to develop into.

The Narrator, Rich Tobia's and Harry Compton's voices are heard again as the monitoring effort is highlighted.

Narrator: A comprehensive monitoring program was set up to measure the results of the study.

Rich: 3:27:36:00 Next year we will come out and we will actually do sampling of the leaves, possibly the stems, possible cores or routes of the trees that we will sample and analyze for both volatile organics and for metals. **3:28:13:00** We'll also be measuring rates of water flow in the tree so we can get an idea of how many gallons/year that these trees are actually taking out of the ground water. And if we can correlate that to how much organics are being given off by the tree we can determine what is going on.

3:27:50:00 We are also going to look at the growth rate of the tree and measure that.

Harry: 2:06:19:00 We are going to have to evaluate this over a number of years, probably two or three years to figure out exactly what's going on and how effective it will be over time. But since there is not an acute threat and we have the luxury of time, this technology works out to be very well for this particular area.

The last monitoring shot dissolves into shots of the "Magic Marker" phytoremediation site in Trenton, New Jersey as the narrator details phytoremediations positive public perception.

Narrator: The technology also has a positive public perception. Communities near a contaminated site may be more receptive to a "green" solution like phytoremediation rather than excavation or incineration. In fact, at another pilot scale study taking place in Trenton New Jersey, the community has taken on an active role at the site.

Frank McLaughlin, a hydrogeologist for the New Jersey Department of Environmental Protection appears and explains.

Frank 12:09:58:00: The community response to this phytoremediation demonstration project has been tremendous. **2:11:04:00** This site has traditionally had some vandalism problems, and now actually the neighborhood residents police the site to prevent vandalism and other problems. So the community acceptance has been wonderful and they are actually helping the remediation by watching the plants for us and the irrigation equipment.

Footage of the Trenton site reinforces the narrators statement.

Narrator: While the Aberdeen site is remediating organics only, the study in New Jersey is focusing on remediating metals, a process many researchers believe presents a formidable challenge.

Mike Blaylock, a research scientist for Phytotech appears and describes what makes metals decontamination different from organics.

Mike 12:25:15:00: The remediation of metal-contaminated soils is a little bit different than remediating organic contaminants in soils. Organic contaminants can often be degraded, volatilized, there are ways to get rid of them naturally or through the stimulation of adding something to the soil. Metals, on the other hand, are there to stay. You actually have to remove the metal physically. They can't be degraded, they generally don't volatilize.

As the narrator and Frank detail the site footage of the old buildings and the remediation effort appear.

Narrator: The test site is located at an abandoned industrial facility that's operated in different capacities since the turn of the century. The production of everything from batteries to magic markers has left a legacy of contamination.

Frank 12:03:27:00: Throughout most of the site, we have lead contamination above our state cleanup guidelines of 400 ppm. The lead originated during the lead battery manufacturing that occurred here in the 1940s through the 1970s. There is also some fuel oil contamination, some PCBs associated with the transformer down the further end of the building. But the majority of the contamination at the site is metal related and primarily lead from the lead battery manufacturing processes.

Close ups of the plants and shots of Mike and his crew working at the site are seen.

Narrator: After evaluating a number of species, the brasica family of plants was found to yield the most positive results in remediating the lead contaminated soils.

Mike 12:23:51:00 We found this particular crop which is an Indian mustard, it is grown as a oil seed or as a forage crop and we screened (**edit)** several hundred different varieties of this particular species to find one that would accumulate a high concentration of metals into the shoots. And then after we found those then we took this into the field to test it in the field and found that (**edit)** with the addition of some different soil amendments we can stimulate and enhance the uptake of that metal into the shoots.

Shots of Mike and his crew sampling as well as starting up the irrigation system are seen.

Mike 12:21:52:00 We've been encouraged by our results this year. They have been very positive in that we are able to reduce the amount of surface contamination substantially. We took where this site originally had about 45% of the site was above 400 ppm. Now less than 25% is above 400 ppm. So we have decreased the amount of area that is contaminated quite significantly.

Shots of another remediation site are shown as well as shots of cattle grazing.

Narrator: These kind of results are encouraging, but the technology does have limitations. Contaminates at some hazardous waste sites are just too deep for tree roots to reach and there's also a concern that animals that eat toxic plants may carry the contaminates through the food chain.

Solutions such as treating the deepest contamination through conventional methods first and fencing sites from animals are being proposed.

These limitations aren't slowing researchers though, who are estimating the cost savings to be fractional compared to the price of conventional methods.

Dr. Cunningham returns for a final time to give his assessment on costs.

S. CUNNINGHAM 7:07:06:00 Our cost analysis suggests that one form of this, where we use plants and soil amendments, where you actually plow these things into the soil, suggests that it is about only 20% of any other kind of soil remediation technology that we have when you are actually out on the field site.

"Best Of" shots from Dr. Cunning hams lab, the Aberdeen site and the Trenton site dissolve together as the story wraps up.

Narrator: Researchers like Dr. Cunningham, Mike Blaylock, and the scientists at the Aberdeen site are enthusiastic, but more investigations need to be conducted. Agronomists and remediation experts now need to collaborate to develop specialized plants and techniques for specific remediation needs.

Mike Blaylock: 12:29:19:00 We have elements such as arsenic, radio nuclides, cesium, strontium, uranium, all those things are elements that we are looking at - cadmium and zinc as well. There's a number of metals that we need to develop this technology for. The chemistry in the soil of each one of those elements can be a little bit different.
12:30:06:00 In addition, we'd like to find plants that grow bigger, the more biomass the more vegetation we can produce, the more metal we can remove from the soil in a cropping season, or in one cycle. So we'd like to continue to search for more efficient ways to produce higher yields as far as vegetation as well as finding ways to increase the metal uptake into the plant and stimulating those mechanisms.

Mike 12:29:19:00: As a researcher, phytoremediation is very exciting because there are a number of new avenues that we can continue to study and develop. The field is very young. We're just touching, scratching the surface of the potential of phytoremediation.